Phenomenology of Charm and Bottom Production *

R. Vogt

Previous measurements of the $c\overline{c}$ production cross section at $\sqrt{S} \leq 63$ GeV suggested that the Born cross section underpredicted the data by a factor of two to three, called the K factor after a similar situation in Drell-Yan production,

$$K_{\rm exp} = \frac{\sigma_{\rm data}(AB \rightarrow Q\overline{Q})}{\sigma_{\rm theory}(AB \rightarrow Q\overline{Q})} \ , \tag{1}$$

where Q is the produced heavy quark. An analogous theoretical K factor can be defined from the ratio of the next-to-leading order (NLO) to the Born cross sections,

$$K_{\rm th} = \frac{\sigma_{\rm NLO}(AB \rightarrow Q\overline{Q})}{\sigma_{\rm Born}(AB \rightarrow Q\overline{Q})} \ , \tag{2}$$

where $\sigma_{\rm NLO}$ is the sum of the Born and $\mathcal{O}(\alpha_s)$ corrections. The NLO cross section is strongly dependent on the choice of the renormalization and factorization scales, μ_R and μ_F, which determine both $K_{\rm exp}$ and $K_{\rm th}$.

We discuss the scale dependence of c and b quark production and its influence on the K factors. We adjust the scales and the heavy quark mass, m_Q, to achieve $K_{\rm exp}^{\rm NLO} \approx 1$ [1] keeping in mind that further corrections to the cross section could also be large. Our calculations are done with a Monte Carlo program developed by Nason and collaborators [2].

The physical cross section should be independent of the scale. If the perturbative expansion is convergent, *i.e.* if further higher-order corrections are small, at some scale the $\mathcal{O}(\alpha_s^{n+1})$ contribution to the cross section should be smaller than the $\mathcal{O}(\alpha_s^n)$ contribution. If the scale dependence is strong, the perturbative expansion is untrustworthy. Since $K_{\rm th} - 1 > 1$, further higher-order corrections are needed, particularly for charm and bottom quarks which are rather "light" when $\sqrt{S}$ is large. Although the scales are, in principle, independent, we take $\mu_F = \mu_R = \mu$ because this assumption is inherent in global analyses of parton densities.

In calculations of the total cross section, $\mu \propto m_Q$. However, for single inclusive or double differential distributions, it may be more appropriate to choose a scale proportional to the transverse momentum of the heavy quark, p_T, or its transverse mass, m_T. A constant scale would be appropriate if $m_Q \simeq p_T$, but generally $m_c \ll p_T$ and $m_b \ll p_T$ at collider energies. Therefore the p_T dependent scale absorbs (resums) large logarithmic terms such as $\ln(p_T/\mu)$ appearing when $p_T \gg m_Q$ and producing collinear divergences which are unregulated if $\mu = m_Q$.

Since the $Q\overline{Q}$ pair distributions are essential to determine their contribution to lepton pair production, it would be convenient if the nontrivial distributions could be modeled by the Born distributions to within a constant $K_{\rm th}$. With $\mu \propto m_T$, $K_{\rm th}$ is nearly constant, even in a regime where $m_Q \ll \sqrt{S}$ although some variations occur near the boundaries of phase space. Thus event generators for heavy quark production can, with relative confidence, scale all non-trivial Born results. Thus for heavy quark and quark pair distributions calculable at the Born level, $K_{\rm th}$ is nearly constant provided that $\mu \propto m_T$. The actual value of $K_{\rm th}$ can be determined by a comparison of the NLO and Born total cross sections.

[1] P.L. McGaughey *et al.*, Int. J. Mod. Phys. **A10** (1995) 2999.

[2] M.L. Mangano, P. Nason, and G. Ridolfi, Nucl. Phys. **B373** (1992) 295; M.L. Mangano, P. Nason, and G. Ridolfi, Nucl. Phys. **B405** (1993) 507.

*LBL-37105; Z. Phys. **C71** (1996) 475.